Energy-efficient lighting for housing

– exemplars for builders, installers, owners and managers

The benefits of using energy-efficient lighting in domestic buildings are:

- reduced energy costs
- reduced maintenance frequency
- lower carbon emissions.

GOOD PRACTICE CASE STUDY 361

ENERGY EFFICIENCY
BEST PRACTICE PROGRAMME

CONTENTS

1 INTRODUCTION

Most people are aware of the financial benefits of the efficient use of central heating systems or cookers, because they normally represent a significant proportion of the energy bill. Less well appreciated are the savings to be made by adopting energy-efficient lighting practices in the home. Lighting represents a relatively small proportion (typically 5%) of the energy consumed, so many householders feel that it is not worth while making savings in this area. However, lighting uses electricity, which is several times more expensive per unit (kWh) than fossil fuels (oil and gas). Consequently, the energy used for lighting represents something close to 15% of the total cost of the energy used in the dwelling. If householders were aware of the true cost of lighting then energy-efficient lighting would be seen as a much more attractive investment.

This Case Study shows how domestic lighting can be operated both efficiently and cost-effectively. The examples relate to both multi-residential accommodation and to privately owned houses. Consequently, this publication will be of interest to installers, builders, owners and managers of buildings with single and multiple occupancy.

Any proposal to install energy-efficient lighting should consider:

- the lighting level required (illuminance)
- the energy consumption of each lamp
- the capital cost of equipment and the payback period
- maintenance requirements
- expected lamp life.

Five case histories are described below; one representing each of the three major multi-residential housing sectors and two representing the private domestic sector.

The multi-residential buildings are:

- Montgomery of Alamein Court, Bracknell
- Panns Bank, University of Sunderland
- Moreton Tower, West London.

Montgomery of Alamein Court houses elderly residents within a sheltered environment, while Panns Bank is a student hall of residence. Moreton Tower is a typical inner-city residential tower block. The three buildings represent three distinct design solutions: each building is a different size, and each has different lighting requirements.

The individual domestic buildings are:

- Lower Watts house, Charlbury, Oxfordshire
- Eco-house, Woodstock, Oxfordshire.

These two dwellings were selected to demonstrate a range of good practice lighting strategies. Eco-house and Lower Watts house are individually designed houses and, while some thought has gone into reducing their dependency on electric light, there is still a significant requirement for electric light in each case. The lighting in both dwellings is provided by a combination of daylight, low-energy lighting technology and incandescent general lighting service (GLS) lamps.

The case histories illustrate how upgrading to new energy-efficient technologies benefits occupants in terms of both energy costs and the quality of the lighting provided.

INDIVIDUAL DOMESTIC BUILDINGS

The energy use attributable to lighting in the domestic sector has been rising steadily over the past 25 years. Conversion to low-energy lighting technology could reduce the energy used to light a typical domestic dwelling by about 550 kWh, saving £38 per year. This produces reductions of carbon dioxide (CO_2) emissions equivalent to a saving of 89 kg of carbon. So the savings are not merely financial – they are environmental too.

MULTI-RESIDENTIAL BUILDINGS

Multi-residential buildings may be regarded as a collection of individual dwellings connected by common parts (eg corridors, reception areas, lifts etc). Very significant energy savings can be made by using compact fluorescent lamps (CFLs) in the common areas of such buildings.

INTRODUCTION

Other benefits that are more difficult to quantify may result from refurbishment. Various reports have suggested that security in thoroughfares (eg stairways) in multi-residential buildings is improved by the provision of better lighting. The use of energy-efficient lighting techniques in such circumstances minimises energy consumption while providing the benefits of security.

In addition, the lower demand for electricity leads to a corresponding reduction in emissions from power stations of the greenhouse gas carbon dioxide (CO_2). (For clarity we will refer to CO_2 in kg of carbon.) Therefore, the appropriate use of low-energy lighting and lighting controls can have positive environmental benefits.

COMPACT FLUORESCENT LAMPS (CFLs)

These are suitable for virtually all applications within domestic and multi-residential buildings. They are particularly suitable for corridor lighting, stairway lighting and communal areas, especially where lighting is required for continuous periods.

They are less suited for:

- areas where frequent switching might occur, eg in toilets
- dimming – which is only possible with some types of CFL (special circuits may be required, details should be obtained from manufacturers).

A CFL fitted with electronic ballast uses approximately 18% of the power of its tungsten filament bulb equivalent, while a 26 mm diameter fluorescent tube lamp with electronic control gear uses approximately 13% of the power of its tungsten filament equivalent.

In general, luminaires designed for use with CFLs are available for most tungsten applications – if just the lamp is being replaced, ensure that the existing luminaire is suitable in terms of both size and light distribution.

LIGHT FITTINGS AND REVERSION

CFLs with integral control gear are available with either Edison screw or bayonet lamp caps, so they can directly replace GLS lamps. However, with this arrangement, when the CFL fails, it can be replaced with a GLS lamp. To avoid this ‘reversion’, install a luminaire with separate CFL and control gear, preferably electronic.

The added benefit is that an electronic ballast has a life span of approximately 30 000 hours, while the life of the lamp itself is only 10 000 hours. Therefore less waste and expense is incurred by replacing the lamp separately. Montgomery of Alamein Court has had the standard GLS lamp luminaires replaced by luminaires with a CFL with separate control gear, to prevent reversion to less efficient lamps at the time of replacement.

2 MULTI-RESIDENTIAL BUILDINGS

MONTGOMERY OF ALAMEIN COURT, BRACKNELL

This property contains 70 sheltered flats, including two warden flats. It is owned and run by Housing 21, an independent housing association traditionally linked to the Royal British Legion. Housing 21 specialises in the provision of multi-residential accommodation for older people.

The corridor, lobby and stairwell lighting at Montgomery of Alamein Court formerly comprised a total of 176 x 40 W incandescent GLS lamps. Corridor lighting ran for 24 hours a day, although only alternate lamps were switched on at any given time using separate circuits. This occurred both before and after refurbishment, due to the layout of the corridors. The low-output 40 W GLS lamps that were in place, coupled with discoloured diffusers, meant that light levels within the corridors were below the lower limit of 20-100 lux range recommended in the CIBSE ‘Code for Interior Lighting’ in corridors of residential homes.

The GLS lamps were replaced with 11 W CFLs in the Autumn of 1995. After the conversion, lux levels had increased by an average of 300%, with all measured levels falling within the lux range recommended by CIBSE.

Table 1 shows the calculated energy savings resulting from the refurbishment. These savings were made despite the large improvement in light levels. The estimated savings in maintenance costs and the capital outlay necessary for the refurbishment have been included in the calculation of the payback period of 3.4 years.

Figure 1 Montgomery of Alamein Court

Figure 2 Corridor lighting at Montgomery of Alamein Court after refurbishment

The total annual reduction in energy consumption is 27 061 kWh. This represents a reduction in CO_2 emissions equivalent to 4400 kg of carbon.

In order to discourage reversion from CFL back to GLS (see box on page 4) Housing 21 installed luminaires which only accept CFLs. The control gear for the lamp is contained in the fitting and does not need to be replaced each time the lamp is changed. The control gear lasts about three times as long as the lamp itself and therefore waste and expense are avoided in replacing the control gear unnecessarily.

	Number of luminaires	Annual hours run per lamp	Annual energy used pre-refurb (kWh)	Annual energy used after refurb (kWh)	Annual cost pre-refurb (£)	Annual cost after refurb (£)	Annual savings (£)	Capital cost of works (£)	Payback period (years)
Internal	176	4380*	30 835	8480	2158	594	1564	See total	See total
External	20	5007	6008	1302	420	91	329	See total	See total
Maintenance					645	560	85		
Total	196		36 843	9782	3223	1245	1978	6625	3.4

Table 1 Calculated energy savings at Montgomery of Alamein Court

*Average lamp use 12 hrs/day

MULTI-RESIDENTIAL BUILDINGS

Figure 3 Panns Bank, Sunderland

PANNS BANK, UNIVERSITY OF SUNDERLAND

University accommodation at Panns Bank, Sunderland became operational in 1994. It is designed to house 271 students. Rooms are organised into shared flats and a number of self-contained maisonettes. The overall floor area is 6400 m^2. The glazing allows natural daylighting to stairways, study-bedrooms and lounge/kitchens. The options available for energy-efficient lighting were investigated during the design stages, and the following were adopted.

- External lighting, which includes low-level bollards, is provided by high-pressure sodium (SON) lamps.
- Stairway lighting is provided by wall-mounted luminaires containing 2 x 24 W fluorescent lamps.
- Lighting controls, including daylight sensors (photocells), proximity sensors (PIRs), and time switches, were installed.
- A typical flat contains 17 lamps, the majority of these being 13 W CFLs, although the kitchen/ lounge area has a tubular fluorescent fitting.
- To promote the efficient use of electricity – including the lighting – each flat has a keymeter pay system, ie the students pay for the electricity they use. Monthly visits to the flats throughout 1995 invariably showed that lights which were not required were switched off (eg within shower rooms, WCs, corridors and hallways).

	Lighting consumption (kWh/yr)	Carbon emissions (kg/yr)	Energy costs (£/yr)
Calculated average with GLS lamps fitted	2460	396	172
Average per sub-metered flat fitted with CFLs	530	85	37
Calculated savings	1930	311	135

Table 2 Calculated energy and cost savings for a six-person flat at Panns Bank, Sunderland

As part of a monitoring project, lighting energy consumption in four of the flats, each housing six students, was sub-metered (see table 2). On average, each of the four flats consumed about 530 kWh (£37 per year) for lighting alone. Table 2 shows typical savings for a flat accommodating six students. Extrapolated over the whole building this gives an overall consumption for lighting within flats of 26 700 kWh (£1869). If the flats had been fitted with 17 x 60 W GLS lamps then the annual energy consumption would have been 123 100 kWh (£8617). Thus a notional reduction of 96 400 kWh in lighting energy use has been achieved. This represents a reduction in CO_2 emissions equivalent to 15 500 kg of carbon.

Analysis of payback periods is complicated by the fact that the students pay for their own electricity through the keymeter system, so savings resulting from the use of CFLs go directly to the students. The University, meanwhile, is responsible for the replacement of spent lamps and these maintenance savings and capital costs will be reflected in the accommodation charges to the students. To simplify matters it has been assumed that ultimately all costs and all savings accrue to the University. Comparing the total lighting consumption within flats with the number of lamps and their ratings shows that the average lamp operates for 4.7 hours per day. Assuming the average life for a CFL is 8000 hours, and 1000 hours for an average GLS lamp, then the overall lifetime savings for each CFL is approximately £25. Payback for each CFL occurs within 14 months. The total savings for installing CFLs by the time every CFL has failed will be approximately £26 000.

MULTI-RESIDENTIAL BUILDINGS

MORETON TOWER, ACTON, WEST LONDON

Built in 1968, this 21-storey building is controlled by Ealing Borough Council. It comprises 100 flats and has a total floor area of approximately 1900 m^2. Most of the flats are occupied by council tenants although some are now leased to private owners. Lighting to the communal areas, such as the lift lobby and the stairway, is maintained by the Council.

A lift lobby lies within the central core on each floor of the building. A limited amount of natural daylight reaches the lobby via a corridor to the building perimeter. Electric lighting is therefore provided 24 hours a day by fluorescent tubes.

In the corridor from the lift lobby, and within the stairway which runs up the side of the building, lighting was provided by 87 x 60 W GLS lamps. Because of the extensive glazing up the side of the building the lamps were controlled by timers and operated for an average of 12 hours each day.

For the refurbishment, each 60 W GLS luminaire was replaced by a 22 W CFL luminaire. It is calculated that this produces an annual energy cost savings of over £1000. With the total costs of the project at approximately £3200, payback should be achieved in just over three years.

Table 3 shows how savings are made, and also the associated reductions in emissions.

Figure 4 Moreton Tower, Acton

	Lighting consumption (kWh/yr)	Carbon emissions (kg/yr)	Energy costs (£/yr)
60 W GLS fittings	22 864	3700	1600
22 W CFL fittings	8383	1400	587
Saving	14 481	2300	1013

Table 3 Savings from lighting refurbishment at Moreton Tower

3 DOMESTIC BUILDINGS

Figure 5 Combination lighting within the kitchen of Lower Watts house

Figure 6 Uplighting in the stairway at Lower Watts house

	Lower Watts	Eco-house
Total load (W)	1379	1117
Annual energy consumption (kWh)	450	618
Annual energy consumption/floor area (kWh/m^2)	1.55	2.38
Estimated annual energy costs (£/year)	32	43
Estimated annual energy costs for GLS equivalent (£/year)	80	92
Annual energy cost savings (£/year)	48	49
Carbon savings (kg/year)	110	110

Table 4 Energy use and savings for lighting Lower Watts house and Eco-house

LOWER WATTS HOUSE, CHARLBURY, OXFORDSHIRE

Lower Watts house was designed to fit in with the existing medieval stone buildings that surround it in Charlbury's conservation area. As a consequence, daylighting is limited due to the orientation proximity of other buildings.

Electric lighting is provided by a combination of technologies. Sixty-five percent of the total lighting load comes from fluorescent lamps.

Within the kitchen area (figure 5) there are two fluorescent tubes in diffusing luminaires which provide a good overall lighting standard. There are also recessed ceiling luminaires housing CFLs which are directed at areas that require localised illumination, such as surfaces for food preparation. Although the total lighting load is high at 147 W, it is unlikely that the full load is ever used at one time. Limited daylighting is available during the morning.

The stairs and landing are lit at several points by CFLs housed within uplighting luminaires attached to the wall (an example of which can be seen in figure 6). The combined use of CFLs and uplighting luminaires provides a good lighting level and reduces maintenance.

The use of GLS lamps is confined mainly to rooms that are rarely used or where switching takes place frequently, such as the shower room and the toilet. In applications like these the use of such GLS lamps is acceptable because the energy used is relatively small.

The total maximum lighting load for Lower Watts house is 1379 W, with annual energy consumption per floor area of 1.55 kWh/m^2. This results in an estimated lighting energy cost of £32 per year. This is very low and represents a saving of £48 in energy costs when compared to the equivalent GLS lamps. It represents a reduction in CO_2 emissions equivalent to about 110 kg of carbon per year.

DOMESTIC BUILDINGS

Figure 7 Rear elevation of Eco-house

ECO-HOUSE, WOODSTOCK, OXFORDSHIRE

Eco-house has several unusual design features. It is wide and shallow and the rear elevation faces south. Integrated into the rear elevation is a two-storey sunspace (which can be seen in figure 7). This large glazed area, combined with the shallow depth of the dwelling, allows daylight to penetrate most rooms.

The sunspace also acts as a buffer zone between the interior of the house and outside, enabling passive solar heat gains to be retained more effectively. On the roof there is an array of photovoltaic solar cells and several solar water heaters. Any excess electrical power generated by the cells is transferred to the grid.

Electric lighting is provided by a combination of CFL and GLS lamps. The GLS lamps are responsible for more than half (56%) of the total maximum lighting load. CFL lamps account for the other 44%.

The use of low-power (25 W) GLS spotlight lamps in the kitchen, lounge and hallway is largely for aesthetic purposes. This localised illumination in the kitchen is useful, however, for specific tasks such as food preparation. The increase in total maximum lighting load due to these spotlights is 375 W. They are not intended to be switched on for prolonged periods or used simultaneously with other lighting.

With the exception of the spotlights, the use of GLS lamps is confined strictly to areas where lighting is rarely needed or where switching takes place frequently, such as in the bathroom or toilet.

The total maximum lighting load is 1117 W, with annual energy consumption per floor area of 2.38 kWh/m^2. The estimated annual lighting costs are low at £43. The savings are estimated to be £49 per year compared to the equivalent GLS lamps. The CO_2 emission savings are similar to Lower Watts house and are equivalent to approximately 110 kg of carbon per year.

4 SUMMARY

CFLs not only improve energy efficiency but also reduce maintenance requirements. Energy-efficient lighting can therefore be seen as part of the overall design concept. Issues such as the location and orientation of windows will affect the appropriate use of controls, for example. Maximum use of daylighting from diffuse sunlight should be made where local geography and site orientation allow.

The use of energy-efficient lighting requires an initial extra capital outlay. In two of the three multi-residential case histories, GLS lamps had until recently been used for corridor lighting. By replacing these lamps with CFLs long-term benefits are provided, but with a short-term payback. The simple payback period was just over three years.

Panns Bank illustrates some of the energy efficiency techniques that can be adopted in multi-residential establishments. Examples of energy-efficient controls include daylight sensors and proximity sensors on external lighting and timer switches on stairway lighting. SON lamps for external lighting and CFLs for internal lighting are examples of energy-efficient light sources.

Appropriate lighting levels are provided in each of the properties studied. An assessment of the lighting load/floor area of Eco-house and Lower Watts house shows that they have an annual consumption of 2.38 kWh/m^2 and 1.55 kWh/m^2 respectively, while providing adequate lighting levels. These figures compare very favourably with the estimated annual lighting consumption for the housing stock of 2 kWh/m^2 with CFLs throughout, and demonstrate significant savings achieved against a GLS-only installation of 8 kWh/m^2. Thus it is possible to achieve extremely low lighting loads in practice.

Careful choice of luminaires enables light to be directed into specific areas and on to specific surfaces. The use of CFLs within luminaires designed for GLS lamps can cause problems due to the larger size of CFLs. This problem has been addressed to an extent by both lamp and luminaire manufacturers, and the incidence of part of a CFL extending beyond the luminaire is now less common.

The use of sophisticated lighting controls such as occupancy detectors, proximity sensors and time switches can save energy in many situations, but their absence does not necessarily imply a poor lighting strategy. They can be particularly valuable in multi-residential buildings where residents may be less than conscientious about energy efficiency in the communal areas. However, within domestic buildings sophisticated controls are likely to be superfluous where 'good housekeeping' habits prevail.

DISPOSAL OF SPENT LAMPS

All discharge lamps contain toxic components. A 4 ft-long fluorescent tube may contain over 30 milligrams of mercury. Such tubes must be disposed of responsibly, so that there is no chance of the mercury leaking into the water table (the EU permissible limit for mercury in drinking water is only one part per billion). For multi-residential buildings in particular there is the possibility of bulk disposal of fluorescent lamps, in which case they should be treated as hazardous waste and disposed of at a licensed site, details of which can be obtained from the local authority.

5 GLOSSARY OF TERMS

Average lamp life. The time when half the lamps in a batch under test conditions have failed.

Ballast (or control gear). Apparatus to start and control the current through the lamp. Lamps fitted with electronic control gear have the advantage of better start-up operation and less flicker during operation.

CFL. Compact fluorescent lamp. A low-pressure mercury discharge lamp (see fluorescent lamp).

Diffuser. A translucent screen used to shield a light source and at the same time soften the light output and distribute it evenly.

Discharge lamp. A lamp where the light is produced by an electric discharge through a gas, a metal vapour, or a mixture of gases and vapours.

Fluorescent lamp. A mercury-vapour electric discharge lamp having the inside of the bulb or tube coated with fluorescent material so that ultraviolet radiation from the discharge is converted to light of an acceptable colour.

GLS lamp. General lighting service lamp. This is the tungsten filament lamp.

Illuminance. The amount of light falling on a given surface. The unit of illuminance is the lux, equal to one lumen per square metre (lm/m^2).

Incandescent (or filament) lamp. The filament of an incandescent lamp is heated to somewhere in the region of 2700 K and emits radiation over a wide spectrum range including the visible and infrared regions.

Luminaire. The correct term for a light fitting, it is the complete lighting assembly including lamp, fixings, and fittings necessary for connection to the supply circuit.

Lux. The SI unit of illuminance, equal to one lumen per square metre (lm/m^2)

Power factor. The ratio of watts to volt-amps. It indicates the efficiency with which power supplied by the generating station is used. The higher the power factor the better, 1 (unity) being the maximum.

SON. High-pressure sodium lamps used as external floodlights for amenity and security lighting.

Uplighter. Luminaires that direct light upwards on to the ceiling or upper wall to illuminate the working plane by reflection.

Working plane. The horizontal, vertical or inclined plane on which the task lies. It is normally assumed to be horizontal at 0.85 m above the floor, unless otherwise indicated.

FURTHER READING

FURTHER READING

Chartered Institution of Building Services Engineers (CIBSE)

Delta House, 222 Balham High Road
London SW12 9BS. Tel 0181 675 5211

- CIBSE Code for Interior Lighting (1994)
- CIBSE Applications Manual AM4 Security Engineering (1991)

H and H Scientific Consultants Ltd (HHSC)

PO Box MT 27, Leeds LS17 8RA
Tel 0113 268 7189

- Handbook 7 'Lighting for occupational hygienists' (1991)

DETR ENERGY EFFICIENCY BEST PRACTICE PROGRAMME PUBLICATIONS

The following Best Practice programme publications are available from BRECSU Enquiries Bureau. Contact details are given below.

Introduction to Energy Efficiency

4 Health care buildings

Good Practice Case Studies

86 Low energy lighting in the communal areas of housing. Energy efficiency in the communal areas of housing in the London Borough of Enfield

236 Low energy design of care homes – the cost-effective route to energy efficiency

284 Energy efficiency in care homes. Batley Hall nursing and residential home

Good Practice Guides

159 Converting to compact fluorescent lighting – a refurbishment guide

192 Designing energy efficient multi-residential buildings

199 Energy efficient lighting – a guide for installers

New Practice Final Report

80 New low energy multi-residential accommodation. Constable Terrace, University of East Anglia

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Energy Efficiency Best Practice in Housing

Tel: 0845 120 7799
www.est.org.uk/bestpractice

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